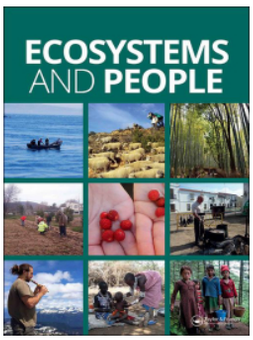

Ecosystems and People

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tbsm22

Identifying leverage points for strengthening adaptive capacity to climate change

Linda M. Rosengren, Christopher M. Raymond, Mila Sell & Hilkka Vihinen

To cite this article: Linda M. Rosengren, Christopher M. Raymond, Mila Sell & Hilkka Vihinen (2020) Identifying leverage points for strengthening adaptive capacity to climate change, Ecosystems and People, 16:1, 427-444, DOI: 10.1080/26395916.2020.1857439

To link to this article: https://doi.org/10.1080/26395916.2020.1857439

ECOSYSTEMS AND PEOPLE
2020, VOL. 16, NO. 1, 427–444
https://doi.org/10.1080/26395916.2020.1857439

Taylor & Francis
Taylor & Francis Group

RESEARCH: HUMAN-NATURE CONNECTEDNESS AS LEVERAGE POINT

Identifying leverage points for strengthening adaptive capacity to climate change

Linda M. Rosengren [a,b], Christopher M. Raymond [c,d,e], Mila Sell [b] and Hilkka Vihinen [b]

[a]Faculty of Agriculture and Forestry, Department of Agriculture Science, University of Helsinki, Helsinki, Finland; [b]Unit of Bioeconomy and Environment, Natural Resources Institut Finland (Luke), Helsinki, Finland; [c]Helsinki Institute for Sustainability Science (HELSUS), University of Helsinki, Helsinki; [d]Ecosystems and Environment Research Program, Faculty of Biological and Environmental Sciences, University of Helsinki, Helsinki, Finland; [e]Department of Economics and Management, Faculty of Agriculture and Forestry Sciences, University of Helsinki, Helsinki, Finland

ABSTRACT

Leverage points from systems research are increasingly important to understand how to support transformations towards sustainability, but few studies have considered leverage points in strengthening adaptive capacity to climate change. The existing literature mainly considers strengthening adaptive capacity as a steady and linear process. This article explores possibilities to fast track positive adaptive capacity trajectories of small-scale farmers in the Northern Region of Ghana. Leverage points were identified by triangulating data from semi-structured interviews with farmers (n=72), key informant interviews (n=7) and focus group discussions (FG1 n=17; FG2 n=20). The results present two ways to approach adaptation planning: 1) using four generic leverage points (gender equality, social learning, information and knowledge, and access to finance) or 2) combining the adaptive capacity and leverage point frameworks, thereby creating 15 associations. The generic points provide a set of topics as a starting point for policy and intervention planning activities, while the 15 associations support the identification of place-specific leverage points. Four benefits of using leverage points for adaptive capacity in adaptation planning were identified: guidance on where to intervene in a system, ability to deal with complex systems, inclusion of both causal and teleological decision-making, and a possibility to target deep, transformative change.

ARTICLE HISTORY
Received 2 December 2019
Accepted 24 November 2020

EDITED BY
Jacqueline Loos

KEYWORDS
adaptive capacity; leverage points; climate change adaptation; transformation; sustainability

Introduction

Climate change increasingly poses a number of new stressors on people and ecosystems (Ripple et al. 2019), particularly on agricultural systems in the Global South (Hirabayashi et al. 2013; Wheeler and Von Braun 2013; Caminade et al. 2014; Roy 2018). Africa's agricultural sector, providing the livelihoods of nearly 80% of the continent's population, is highly sensitive to climate change (Sonwa et al. 2017). A projected further increase in extreme heat events, changes in rainfall patterns and increasing aridity pose a threat to nearly the entire (96%) rain-fed crop production (Serdeczny et al. 2017). To respond to these challenges a rich literature on climate change adaptation has developed during recent decades (Descheemaeker et al. 2016; Sultan and Gaetani 2016; Muchuru and Nhamo 2019).

This article investigates one of the main concepts of climate change adaptation, namely adaptive capacity. While there is no one single-established definition of adaptive capacity, it can be broadly defined as 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences' (IPCC 2014, p. 1758). Adaptive capacity is not simply about having the necessary resources at hand but also about the willingness and capability to convert resources into effective adaptive action (Brown and Westaway 2011; Cinner et al. 2018). People's ability to adapt to climate change in an African agricultural context is commonly influenced by age, farm size, the nature of farming, and access to the market and extension services (Gbegbelegbe et al. 2018), with variations in determinants across pastoralists, agro-pastoralists and smallholder farmers (Menghistu et al. 2020).

The existing adaptive capacity literature is extensive but fragmented with little cross-referencing, leading to questions regarding how effectively the field is advancing the science of adaptive capacity (Siders 2019). One obvious explanation to why there have been so many methods, frameworks and indicators developed to assess the adaptive capacity is that adaptive capacity and adaptation in general are place- and context-specific (Armah et al. 2015; Siders 2019). While case studies bringing understanding of place- and context-specific adaptive capacity in the Global South are valuable, we are concerned that most scholars have generated 'laundry lists' of barriers to, and

CONTACT Linda M. Rosengren linda.rosengren@luke.fi

enablers of, adaptive capacity without diagnosing which elements of adaptive capacity have the greatest promise in transforming agricultural systems into more sustainable pathways. Further, despite the urgent need for more research on transformative adaptation (IPCC 2014), few studies identify context-sensitive ways to link adaptive capacity with concrete action (Whitney et al. 2017).

Many studies have assessed the adaptive capacity of households, communities and organizations in the Global South, in addition to barriers to adaptation. Commonly identified barriers include biophysical, knowledge, and financial constraints on agricultural production and rural development (Shackleton et al. 2015). Community and gender differences have been found to influence adaptive capacity among farmers. More limited access to education, less mobility and weaker agency hinders women from seeking expert support (Cohen et al. 2016). Women often perceive the impacts of climate change and apply adaptation measures differently compared with men (Oloukoi et al. 2014; Twyman et al. 2014), which has been attributed to women having less access to climate information as well as information about options for responding to climate change (Bernier et al. 2015). The institutional context, including the structure of interactions, and the way in which knowledge is shared and evaluated are also important barriers (Shackleton et al. 2015).

The objective of this article is to identify and contextualize leverage points for the strengthening of adaptive capacity of small-scale farmers in the Northern Region of Ghana. Leverage points as presented in this study refer to 'places in complex systems where a small shift may lead to fundamental changes in the system as a whole' (Abson et al. 2017), a concept stemming from systems thinking or systems research. We connect two established literature themes: adaptive capacity and systemic leverage points. We contend that new forms of leverage points emerge when considering associations between established domains of adaptive capacity and established types of leverage points. By combining these two concepts we identify new place-specific 'leverage points for strengthening the adaptive capacity' of farmers in the Northern Region of Ghana. The geographical scope of the study was based on the need to further understand advancing adaptive capacity in vulnerable and drought-sensitive countries in the Global South.

Both leverage points and adaptive capacity relate to change. While the concept of leverage points proposes a possibility to create change in any given system, the adaptive capacity concept brings the focus explicitly to the latent ability to adjust to climate change by exploring the barriers and enablers (Engle 2011; Angeler et al. 2019). The existing literature mainly considers the process of strengthening adaptive capacity as a steady and linear process (Garschagen and Soletzki 2017; Fuchs and Thaler 2017). This article on the other hand explores possibilities to fast track positive adaptive capacity trajectories using the transformational potential of the leverage points. We argue that targeting interventions at the identified leverage points in a given food and agriculture systems can improve the latent capacity of farmers to adapt to existing and new challenges imposed by climate change in abrupt, non-linear, and efficient ways.

Theoretical background to leverage points and adaptive capacity

Leverage points

Leverage points have recently gained an increasing amount of interest in sustainability and transformation research due to their potential to facilitate change. Leverage points studies as part of climate change adaptation research are limited but exist. Leverage points were studied to inform adaptation to climate change to improve human health (Proust et al. 2012) and in relation to responses to drought (Rhoades et al. 2014). However, few studies identify leverage points to strengthen the adaptive capacity to climate change.

A leverage point framework describing 12 different types of place to intervene in a system was originally published in 1999 by Donella Meadows, a pioneer in development science. The 12 different types of systemic points are organized hierarchically according to the potential to create change. The points with limited power to create change are referred to as 'shallow' or 'weak', and the leverage points with great power to create change are called 'deep' leverage points. Abson et al. (2017) later grouped the 12 leverage points into four realms as shown in Table 1.

This study focuses on the 'design' realm, which is classified as a deep leverage point. The design realm targets the social structures and institutions that manage feedbacks and parameters. The realm includes three types of leverage points: 1) the structure of information flows, 2) the rules of a system and 3) the power to add, change or self-organize. We chose this focus to target deep leverage points with the potential to create broad and transformative change.

Adaptive capacity

We drew upon the framework by Cinner et al. (2018) depicting five distinct domains for adaptive capacity to climate change: assets, flexibility, social organization, learning and agency. *Assets* are financial and technological and can be individually or publicly owned. An asset can also be access to a service, such as healthcare. *Flexibility* 'reflects opportunities for switching between adaptation strategies and captures the diversity of potential adaptation options available' (p. 118). *Social organization* refers to the nature of the relationship between individuals, communities and organizations, including both formal and informal relationships. Social organization defines how knowledge sharing,

Table 1. The table visualizes the relationship between the four realms of Abson et al. (2017) and the twelve systemic leverage points of Meadows (1999) and examples of leverage points for climate action in an agricultural context. The table is adapted from Fischer and Riechers (2019). The design realm, which is the focus of this study, is highlighted.

Realms of leverage (Abson et al. 2017) (from shallowest to deepest)	Leverage point 12-step framework (Meadows 1999)	Examples of leverage points for climate action in an agricultural context
Parameters	Constants, parameters, numbers	Level of farming subsidies that incentivizes climate-smart agriculture
	Size of buffer stocks, relative to flows	Diversity of agricultural crops and varieties
	Structure of material stocks and flows	Nutrient run-off from fields into water systems
Feedbacks	Length of delays, relative to rate of system change	Climate change mitigation measures that slow climate change, e.g. reduction of farming systems with extensive grazing that leads to deforestation
	Strength of negative feedback loops	Climate change adaptation measures that enable agricultural production despite increasing temperatures, e.g. more drought-resistant crops
	Gain around positive feedback loops	Increase in population growth and meat consumption
Design	Structure of information flows	Access to agricultural extension services
	Rules of the system (incentives, constraints)	Land use rules that control the expansion of agricultural land to pristine, biodiversity rich, natural forest
	Power to change system structure or self-organize	Self-organized farmer-based organizations in the Global South that advocate climate justice
Intent	Goals of the system	Policies and organizations that steer food systems towards low food prices – not towards climate-smart food systems and global food security
	Paradigm underpinning the system	Social norms and values that steer our world view of the structure of food systems
	Power to transcend paradigms	Acceptance that alternatives to the present climate regime and food system exist and are within reach

collective action and cooperation are organized within a society. Important concepts within social organization are bonding capital, bridging capital and linking social capital. Bonding capital refers to the trust and social cohesion in a community. Bridging capital refers to building connections across scales, both horizontally and vertically. Linking social capital also refers to interaction across scales that can enable shared values and provide an opportunity for people facing climate crises to participate in adaptation planning (Pretty 2003).

Cinner et al. (2018) define *learning* in the context of adaptive capacity to climate change as a dynamic process which requires capacity to both process and absorb new information. Learning can take place through various types of activity, both formal and informal, and at various scales. Finally, *agency* provides people with the ability to shape the vision of their own future, adapting and taking necessary action to cope with climate change. A key feature of agency is people's own belief in their ability to make change, thus leveraging the other domains of adaptive capacity.

Materials and methods

Study area

The study was conducted in the Northern Region of Ghana, an area in the savanna agroecological zone (Aniah et al. 2019). This semi-arid climatic area is already experiencing increased temperatures (Abbam et al. 2018) and is highly vulnerable to climate change (Boafo et al. 2016). A study based on daily rainfall data from 1960 to 2007 shows that rainfall patterns have changed (Yengoh et al. 2010). The changes appear as more frequent and more severe floods during the rainy season, late rains during the start of the planting season and persistent droughts during the dry season. Future climate change scenarios predict further continuous and strong increases in temperature of 1.5–6.5°C (Sylla et al. 2016). Figure 1 shows the agroecological zones and the location of the project area.

As agriculture in the region is mainly rain-fed, changes in rainfall patterns have a direct impact on food security and the vulnerability of the predominantly small-scale farmers living in this region (Wossen and Berger 2015). Poverty is widespread, investments are scarce and the ability of the population to cope with shocks is limited (Wossen and Berger 2015). Literacy rates are low especially in the rural areas: 25% for men and only 15% for women (Ghana Statistical Service 2019). Livelihood diversification has been identified as an important climate change adaptation measure for northern Ghana. Livelihood diversification is, however, low especially in rural areas, which further contributes to the vulnerability of the population (Dumenu and Obeng 2016).

Two parallel governance systems exist in the study area: the official or modern system, and the

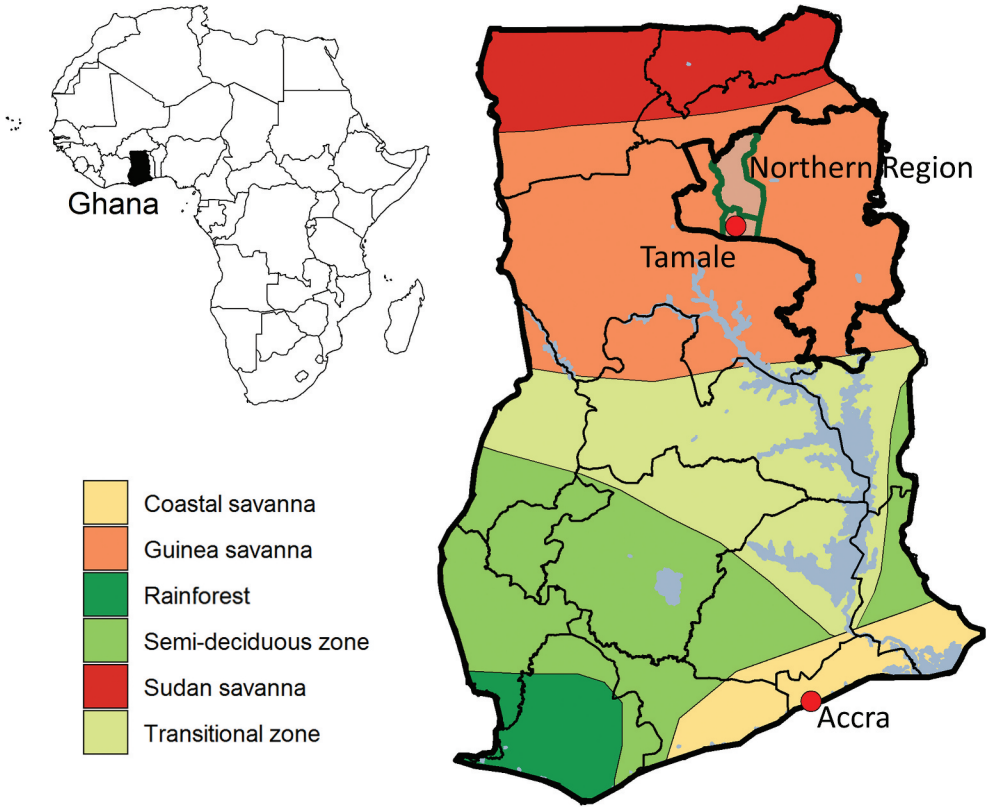

Figure 1. Map of Ghana and the project area in relation to the agroecological zones. The agroecological zones are modified from Osei and Stein (2017).

traditional system or chieftaincy. The latter has a prominent role in setting local norms and values (Owusu-Mensah 2014). In a chieftaincy, a community is led by the chief. All land and natural resources of the community belong to the chief, who can allocate these to members of the community. The area is predominantly Muslim and has a high prevalence of polygamous marriages (Agadjanian and Ezeh 2000). The social structure is patriarchal, placing women in a subordinate role to men. This is reflected in girls' lower access to education (Atta 2015), marital violence (Tenkorang et al. 2013), sexual harassment of girls by teachers (Atta 2015), forced and early marriage (Hallegatte 2009) and exclusion of women in decision-making regarding livelihood matters (Apusigah 2009).

Data collection

The study was conducted using semi-structured interviews and backcasting in focus group discussions. The semi-structured interview method was selected to capture a rich data set on complex topics and the backcasting in focus groups was selected to harness data on an envisioned desired future and how to reach this vision. The interviews, key informant interviews and focus group discussions were recorded, transcribed verbatim and translated into English.

Interviews

The interviews were conducted by a research team with three Ghanaian members speaking the local language Dagbani and two non-Ghanaians. In the case of the non-Ghanaians the interviews were conducted together with translators. The interviews were conducted at two separate time points: in April 2019 during the dry season and in October 2019 during the rainy season. The reason for this was that the authors wanted to supplement the sample with more male informants for gender balance.

The objective of the farmer sample was to gain information about the farmers' adaptive capacity to climate change and possible leverage points to strengthen their adaptive capacity. The farmer interviews were conducted in the communities after traditional protocol with the approval of the community chief. Each interview lasted approximately 30–40 minutes. The questions related to the impact of climate change and adaptation strategies, as well as to the five domains of adaptive capacity (assets, flexibility, social organization, learning and agency) and the interplay with the three types of leverage points studied (information flows, rules and structures, and self-organization). The set of 36 questions (Appendix 1), including both closed and open-ended questions, was piloted with three members of the sample before collecting the data.

The objective of the key informant interviews was to harness information about the food system and the

challenges that climate change poses in the study area. Key informant interviews lasted approximately 40 minutes. The questions related to the local food system, the role of the different actors within the system, and the potential for change. The questions were tailored to fit the expertise of the informant. One version of the questions is included in Appendix 2. All questions were open-ended.

Backcasting in focus groups

The objective of the focus group discussions was to harness information regarding a desired future, dreams and wishes, and means to realize these to identify possible leverage points. A backcasting exercise was applied in which participants were first asked to envision a desired future and then discuss the required steps to reach it, including what, who and how (Dreborg 1996). To provide the participants with a concrete way of envisioning the future, they were asked to describe the ideal future lives of their children or grandchildren. The backcasting was in broad terms following the methodological framework for backcasting by Quist and Vergragt (2006). The guidance on the backcasting for the facilitators including the given questions is provided in Appendix 3.

The sessions were facilitated by professional facilitators from the University for Development Studies (UDS) in Tamale and the Savanna Agriculture Research Institute and are summarized in a report form by a designated observer. Two focus group discussions included 17 and 20 persons, respectively. The number of participants was intentionally kept low to keep the atmosphere of the meeting unofficial and allow a safe space for active participation.

Prior to data collection, both in the case of interviews and focus group discussions, informed consent was obtained from the participants. All persons approached were willing to participate.

Sampling

Two samples were formed for the interviews: a sample of key informants (n = 7) and a sample of farmers (n = 72). The key informants included a government official, a village chief, two agriproduce processors, an executive member of a farmers' umbrella organization, a professor at UDS and an agricultural extension worker. The key informant sample included five men and two women. The sample of farmers included 26 men and 46 women. Despite the number of men in the study being nearly half that of women, theoretical saturation was also obtained for the men. Theoretical saturation is reached when no further insights emerge during the data analysis, indicating that the sample size is sufficient (Saunders et al. 2018).

The samples were formed through purposive sampling as described by Tongco (2007). The project partners UDS and the Centre for Initiatives on Food Security and Environment (CIFSE) facilitated access to the communities included in the study. Informant selection was executed with the help of an appointee of the community chief in collaboration with the representatives of either UDS or CIFSE. The informants were selected based on gender and social status in the community. Prominent, average and vulnerable individuals were included in the sample. Selection criteria leaned on the vulnerability framework of Füssel (2007b) following three criteria: income, access to networks and access to information. Age was not used as a selection criteria as many of the respondents did not know their age. The key informant sampling was also based on purposive sampling facilitated by UDS and CIFSE.

The farmer sample consisted of persons from five communities (Tugu, Nantong Changnaayili, Kukuo, Young Dakpem, and Langa (Figure 2)) situated within a 40 km radius from the regional capital Tamale. The five different communities were chosen to enable a comprehensive understanding of the context and cultural practices within the communities in the case study area. The traditions varied to some extent but from a livelihood perspective the majority of the community members are small-scale, subsistence farmers and have similar social structures, as described in the 'Study area' section. One of the communities is situated closer to Tamale and therefore has easier access to markets. The communities were selected based on a pre-existing working relationship of the project partners, UDS and CIFSE.

Data analysis

We cross-tabulated the five established domains of adaptive capacity according to Cinner et al. (2018) (assets, flexibility, social organization, learning and agency) with the three established types of leverage points from the framework of Meadows (1999) (structure of information flows, rules of the system and power to add, change, evolve or self-organize) (Tables 2 and 3). This resulted in 15 associations that the study used to identify place-specific leverage points for strengthening the adaptive capacity of small-scale farmers in the Northern Region of Ghana. We conducted thematic analysis using a six-phase approach (Braun et al. 2019), 1) familiarization with the data, 2) generating codes, 3) constructing themes, 4) revising themes, 5) defining themes and 6) producing the report. Phase one included detailed reading of the total 266 pages of transcribed text. The objective of phase two was to identify associations between the two frameworks used in the study. The codes were informed by drawing on the established definitions of the subcomponents of the two frameworks. Phase two was conducted using NVivo software by arranging the data according to three separate folders: 'information flows', 'rules and structures' and 'self-organization'. The

Figure 2. Photograph featuring the village setting in Langa community, Savelugu District, Northern Region, Ghana. Photo taken by Linda Rosengren.

Table 2. The table shows the construction of the cross-tabulation and the 15 associations emerging from combining the five established domains of adaptive capacity by Cinner et al (2018) with the three established types of leverage points of Meadows (1999). Each number presents an association.

	Structures of information flows	Rules of the system	Power to add, change, evolve or self-organize
Assets	1	2	3
Flexibility	4	5	6
Social organization	7	8	9
Learning	10	11	12
Agency	13	14	15

work was largely facilitated by the design of the interview script. Phase three was undertaken inductively with the objective to enrich the understanding of the associations between the leverage points and adaptive capacity. This phase required substantive analytical input. Phase four was an iterative process including merging codes, renaming codes and double-checking the data. Phase five formed the basis for the identification of the leverage points. The identification used the definition of adaptive capacity according to Cinner et al. (2018) and the descriptions of the five domains as a starting point. In the absence of a theory of a suitable identification process of leverage points we applied an inductive approach using three criteria developed by the authors, of which a leverage point should fulfil at least one. The criteria were:

(1) A challenge related to an important element of adaptive capacity.
(2) An encouraging example related to an important element of adaptive capacity.
(3) A limited or completely missing important element of adaptive capacity.

A challenge could for example be an issue related to access to assets or any other of the five domains forming the adaptive capacity according to Cinner et al. (2018). An encouraging example could on the other hand be a finding on how farmers had benefitted from social organization. We found also instances where aspects crucial for adaptive capacity were lacking altogether, which was why we created a third criterion. In some instances an identified leverage point could be based on data including both reported challenges and positive examples.

Next, the results were filtered using a frequency analysis feature in NVivo and cross-tabulated against gender. The dominance of a theme was determined by the respondents reporting on a particular theme quantified in both percentage of persons and the number of persons in relation to the sample's gender pool size expressed as follows (M: xx%, xx pers, F: xx %, xx pers). In the case that an element of the data was mentioned by fewer than four respondents, we state the interview number (IN). For direct quotes the number of the interview is stated and the gender of the respondents is indicated by M/F.

Based on the identified systemic leverage points, we also suggest potential-associated interventions linked to the leverage points based on the local context.

Results

The study set out to identify and contextualize leverage points with the potential to strengthen adaptive capacity to climate change. The 15 identified place-specific leverage points are described here and summarized in Table 3. In some instances, the identified leverage point could fit multiple domains of adaptive capacity because they are closely interlinked. In this case we define why the identified leverage point is placed under a specific domain of adaptive capacity.

Fifteen place-specific leverage points

Assets

Leverage point 1: Access to radio. Radio is a paramount source of information especially among the predominantly illiterate adults in the case study area. Radio was listed as the number one source of information on

Table 3. The 15 place-specific systemic leverage points derived from the collected data and suggested associated interventions for strengthening adaptive capacity. LP = leverage points; INT = intervention.

	Structure of information flows	Rules of the system	Power to add, change, evolve or self-organize
Assets	LP: Access to radio INT: Place a radio in a community space open for all community members and encourage gatherings for the times of the agricultural extension radio programmes	LP: Rules about land tenure INT: Revise the tradition of the removal of trees when acquiring more farmland	LP: System for renting a tractor INT: Introduce a coordination system in the communities for the renting of a tractor
Flexibility	LP: Access to agricultural extension information INT: Encourage all community members to participate in agricultural extension meetings. Provide a radio in a community space.	LP: Rules about access to credit INT: Introduce easily accessible, fair and transparent micro-lending mechanisms with established protocols for lending	LP: Community savings groups INT: Encourage establishment of these
Social organization	LP: Social platforms that provide a continuum of knowledge exchange across scale INT: Establish social platforms that provide this	LP: Rules and traditions regarding interaction in groups INT: Encourage all community members including women to actively speak their minds in meetings	LP: Self-organized social platforms that build trust and social cohesion INT: Establish these
Learning	LP: Access to training to gain new knowledge and learn new skills INT: Organize training for community members to gain new knowledge and skills	LP: Practices regarding participation in agricultural extension sessions INT: Encourage all community members including women to participate in these	LP: Self-organized social platforms for individual and collective learning INT: Establish these
Agency	LP: Access to learning opportunities that lead to empowerment, new insights and understanding	LP: Patriarchal aspects of the culture	LP: Participatory climate change adaptation planning including existing auto-adaptive practices, local knowledge and scientific findings
	INT: Work with a range of local actors (both users and providers of information) to identify new areas where learning opportunities are needed	INT: Reducing patriarchal aspects of the culture and empowering women	INT: Establish well-facilitated planning session for co-developing locally relevant climate change adaptation measures including scientific and indigenous adaptation knowledge

new technologies for example for farming practices (M: 81%, 21 pers, F: 78%, 36 pers), the weather (M: 77%, 20 pers, F: 85%, 39 pers) and credit and loans (M: 46%, 12 pers, F: 33%, 15 pers). Women reported radio to be the second most important source of information on organizations and networks (M: 54%, 14 pers, F: 41%, 19 pers). Weekly radio shows hosted by the governmentally-run agricultural extension service emerged as an important source of information on agricultural practices.

Leverage point 2: Rules about land tenure. Land is a pivotal asset in agriculture. When exploring the traditions, practices and rules related to land tenure, including land ownership, the right to use land and access to new farmland, a number of challenges emerged nearly exclusively for women, highlighting a clear gender bias. Compared with women, men reported owning more land (M: 58%, 15 pers, F: 9%, 4 pers) and having inherited more land (M: 19%, 5 pers, F: 2%, 1 pers). In Nantong Changnaayili it was reported that women were not able to own land (IN 123). Men were reported to be favoured in land allocations (INs 120, 217).

Leverage point 3: System for renting a tractor. A tractor was listed as the most important tool for improving farming (M: 77%, 20 pers, F: 63%, 29 pers). The soil was reported to have become harder (IN 103) and was difficult to work with only a hoe. A tractor is an expensive investment for a small-scale farmer and no respondent owned a tractor. However, several respondents reported renting a tractor (M: 11.5%, 3 pers, F: 41%, 19 pers). During peak season this was reported to be difficult (INs 117, 123, 209, 214). In the past the government had a tractor lending scheme that has not existed for some years (IN 105).

Flexibility

In exploring potential opportunities to strengthen flexibility, the study mapped the livelihoods of respondents in addition to their future hopes and dreams, other potential future livelihoods and what starting the alternative livelihood would require. We also explored the different climate change adaptation measures currently undertaken in the case study area and identified what would be needed to improve adaptation efforts. The three place-specific leverage points for improving flexibility could also be classified under other adaptive capacity domains, mainly 'learning' and 'assets'. The following three leverage points were, however, identified as the most prominent entry points to improve the farmers' flexibility to find new adaptation strategies.

Leverage point 4: Access to agricultural extension information. Agricultural extension was reported as

the second most important source of information on technology among both men and women (M: 35%, 9 pers, F: 17%, 8 pers) and the second most important source of information regarding weather among male respondents (M: 54%, 14 pers). When asked about the type of support needed regarding weather, the respondents most frequently reported needing more information on climate change adaptation, especially in relation to farming practices (M: 31%, 8 pers, F: 30%, 14 pers).

Leverage point 5: Rules about access to credit. Start capital was listed both by men and women as the most crucial factor for engaging in alternative livelihoods (M: 73%, 19 pers F: 80%, 37 pers). We found that considerably more women had access to credit compared with men (M: 11.5%, 3 pers, F: 41%, 19 pers). A number of credit providers were reported to exist and to visit the communities to market credit opportunities. The most common challenge mentioned related to credit was the fear of not being able to pay back the money borrowed (M: 8%, 2 pers, F: 13%, 6 pers).

Leverage point 6: Community savings groups. As stated in the previous point, capital was reported as the most important factor for engaging in a new income-generating activity. A number of community-level savings groups were reported. Group members contribute a small amount of money weekly, which can then be cashed out when needed. The savings groups were identified to hold great promise as a micro-finance scheme and were therefore identified as a leverage point.

Social organization

Leverage point 7: Social platforms that provide a continuum of knowledge exchange across scales. The interviewees reported belonging to a plethora of different groups and communities. A total of 24 different groups were mentioned. There was, however, a lack of platforms where members of the community had the opportunity to interact across scales with members of other communities and with persons from other reference groups within the food system. Therefore, such an arena was identified as a leverage point to strengthen the bridging capital (for a definition of bridging capital see the 'Introduction').

Leverage point 8: Rules and traditions regarding interaction in groups. When asked whether the respondent considered their opinion to be heard in a group, women reported affirmatively considerably less (F: 76%, 35 pers) compared with men (M: 92%, 24 pers). Women reported not participating in community discussions and being restricted from interacting in a group with men present. For example, F208: *Because we are mixed with men in this group, I do not easily speak out.* And F224: *In this community women do not take part in community discussions so I do not know whether my suggestion would be heard.*

Leverage point 9: Self-organized social platforms that build trust and social cohesion. When asked whether the respondents tend to help each other in times of hardship the vast majority responded affirmatively (M: 85%, 22 pers, F: 85%, 39 pers). Examples included if someone falls ill, is in financial crisis, experiences food shortage, or their house is destroyed in a fire or storm. Social platforms has the potential to build trust and social cohesion and was therefore identified as a leverage point.

Learning

Leverage point 10: Access to training to gain new knowledge and learn new skills. Being able to diversify livelihood strategies is an important aspect of adaptive capacity. When asked what the interviewee would need to engage in a desired alternative livelihood, gaining knowledge (M: 23%, 6 pers) and skills (M: 8%, 2 pers) were listed as the second and third most important among men and shared second place among women (F: 11%, 5 pers), after access to start capital.

Leverage point 11: Practices regarding participation in agricultural extension sessions. When the interviewees were asked whether they have participated in an agricultural extension session, women replied affirmatively considerably less than men (M: 77%, 20 pers, F: 52%, 24 pers). The quotes exemplify the finding: F125: *No I haven't because sometimes they come to meet only the men.* F230: *For a woman, you have to be an executive in a group before you are considered or chosen to go.*
The most frequently reported challenge related to meeting attendance was biased in the practices. Men reported favouritism in the selection process, while women reported mostly gender-related bias. Addressing the practices regarding participation in agricultural extension sessions was therefore identified as a leverage point.

Leverage point 12: Self-organized social platforms for individual and collective learning. When asked where the respondents normally learn new things the most common answer among women was 'nowhere' (F: 48%, 22 pers), followed by 'experienced persons' and 'groups and meetings' (both F: 11%, 5 pers). Among men the most common answer was 'groups and meetings' (M: 23%, 6 pers), followed by 'extension workers' (M: 19%, 5 pers). Establishing self-organized social platforms for individual and

collective learning welcoming both men and women was therefore identified as a leverage point.

Agency

Leverage point 13: Access to learning opportunities that lead to empowerment, new insights and understanding. Considerably more men than women reported having attended school for at least a year or more (M: 61.5%, 16 pers, F: 17%, 8 pers). More men than women also reported considering themselves as having opportunities to learn new things (M: 85%, 22 pers, F: 70%, 32 pers). Respondents had a strong belief in the importance of new knowledge both for improving their practices and starting new activities. Providing access to such learning opportunities was thus identified as a key leverage point.

Leverage point 14: Patriarchal aspects of the culture. A fundamental result emerging from the data is that adaptive capacity differs between men and women in the study area. Women did not score as well as men in most of the elements crucial for adaptive capacity. Compared with men women responded to own (M: 58%, 15 pers, F: 9%, 4 pers) and inherit considerably less land (M: 19%, 5 pers, F: 2%, 1 pers), own less livestock (M: 85%, 22 pers, F: 54%, 25 pers), own less mobile phones (M: 96%, 25 pers, F: 59%, 27 pers) and have less access to the internet (M: 11.5%, 3 pers, F: 2%, 1 pers). Women also reported having attended agricultural extension sessions less compared with men (M: 77%, 20 pers, F: 52%, 24 pers), and fewer women had attended school for at least one year compared with men (M: 61.5%, 16 pers, F: 17%, 8 pers). In matters related to agency, men were in a better position compared with women in all aspects. Compared with men, fewer women reported feeling free to join any group (M: 85%, 22 pers, F: 50%, 23 pers), having less opportunities to learn new things (M: 85%, 22 pers, F: 70%, 32 pers), being heard by a larger group (M: 92%, 24 pers, F: 76%, 35 pers) and considering themselves able to decide about their own lives (M: 61%, 16 pers, F: 26%, 12 pers). The only issue that, according to the responses, favoured women was access to credit (M: 11.5%, 3 pers, F: 41%, 19 pers). Figure 3 shows how male and female respondents replied to questions regarding adaptive capacity. The data also reveal that other barriers exist for women to acquire or inherit land (according to unpublished data). In summary, women have a lower level of adaptive capacity compared with men, which is directly linked to religious, cultural and social norms. Addressing equality between the sexes was therefore identified as a leverage point.

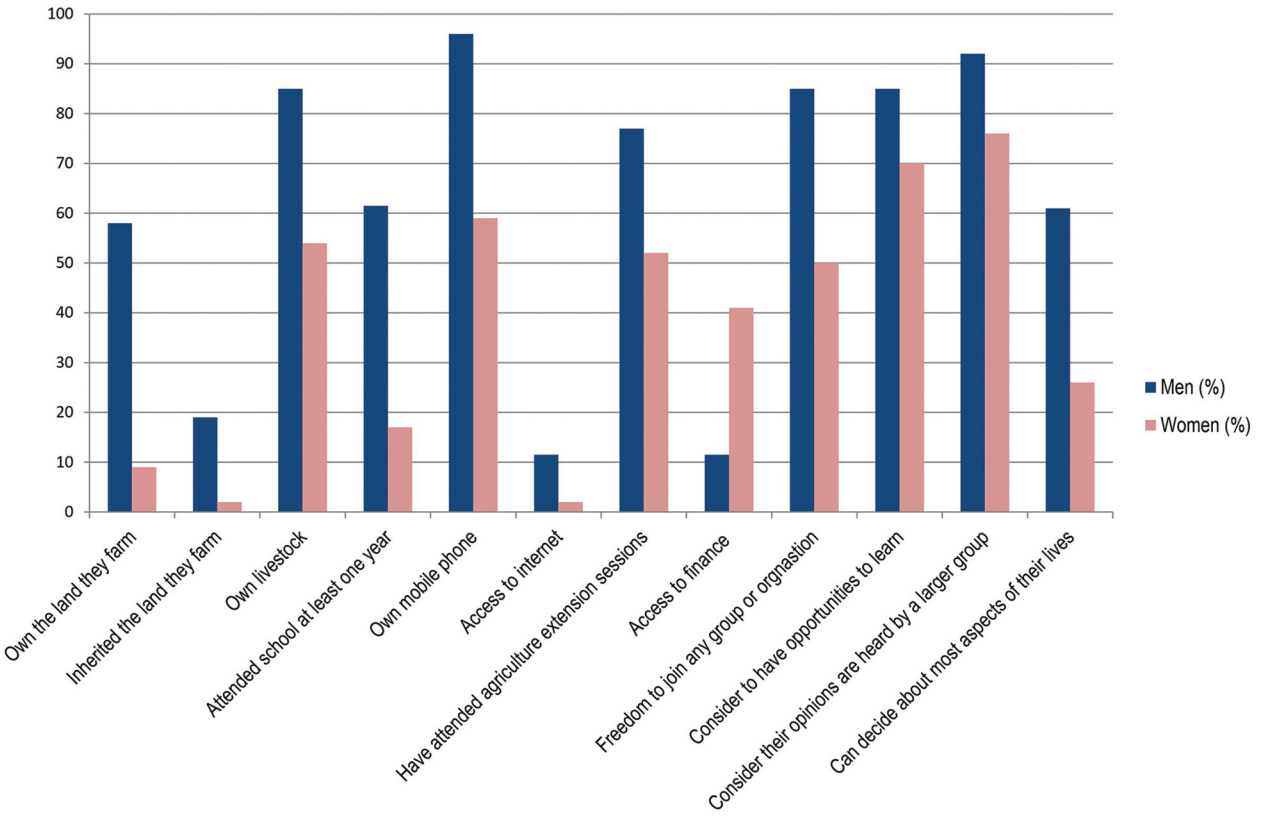

Figure 3. Male and female respondent replies regarding items crucial in determining adaptive capacity according to the definition of Cinner et al. (2018). The percentage is calculated based on the number of affirmative responses in relation to the sample's gender pool size.

Leverage point 15: Participatory climate change adaptation planning including existing auto-adaptive practices, local knowledge and scientific findings. When asked how the respondents had coped with climate change so far, over 23 different adaptation measures were listed. Some of the reported adaptive measures were based on local knowledge and some on advice provided by the agricultural extension officers. Using both local and scientific knowledge as a basis for adaptation planning as well as using participatory approaches for the adaptation planning was therefore identified as a leverage point.

Four generic leverage points

Based on the 15 identified place-specific leverage points for adaptive capacity, four groupings emerged: 1) gender equality, 2) social learning, 3) access to and use of information and knowledge, including local knowledge, hereafter referred to as and information and knowledge and 4) access to finance. Figure 4 illustrates the association between the four groupings and the 15 place-based leverage points identified for the case study. Despite the fact that adaptation planning requires place- and context-specific attention, we argue that the four leverage point groupings are applicable more broadly, and especially in the Global South, and merit careful attention in climate change adaptation policy and intervention planning. We justify this claim by leaning towards the existing literature and our empirical findings. We hence interpret these four leverage point groups as generic leverage points for strengthening adaptive capacity to climate change.

Discussion

This study combined the leverage point framework with the adaptive capacity framework to guide the identification of entry points to create positive transformations towards sustainability among farmers in the Global South. As stated in Chan et al. (2020), transformative change towards sustainable pathways entails addressing levers and leverage points to change the fabric of legal, political, economic and

	Structures of information flows	Rules of the system	Power to add, change, evolve or self-organize
Assets	Access to radio	Rules about land tenure	System for renting a tractor
Flexibility	Access to agricultural extension information	Rules about access to credit	Community savings groups
Social organization	Social platforms that provide a continuum of knowledge exchange across scale	Rules and traditions regarding interaction in groups	Self-organized social platforms that build trust and social cohesion
Learning	Access to training to gain new knowledge and learn new skills	Traditions regarding participation in agricultural extension sessions	Self-organized social platforms and collective learning
Agency	Access to learning opportunities that lead to empowerment, new insights and understanding	Patriarchal aspects of the culture	Participatory climate change adaptation planning including existing auto-adaptive practices, customary knowledge and scientific findings

Gender equality
Social learning
Information and knowledge
Access to finance
Social learning + Information and knowledge

Figure 4. Relation between the four generic leverage points for adaptive capacity and the 15 place-specific identified case study leverage points. Dark red = gender equality, dark blue = social learning, light red = information and knowledge, light blue = access to finance. Note the mix of dark blue and light red colour to mark that the leverage point speaks to both social learning and information and knowledge. Gender has a role in all leverage points despite not being explicitly marked in each cell. The figure builds on the conceptual work of Cinner et al. (2018) for adaptive capacity to climate change and the conceptual work of Abson et al. (2017) for leverage points.

other social systems. In this article we share the approach of Chan et al. (2020) but complement it by identifying and structuring two different levels of leverage points: 1) using the construction of the adaptive capacity and leverage point frameworks to create 15 associations and 2) using the four generic leverage points. Both ways provide guidance on spurring positive change and support reflection and planning for strengthening adaptive capacity. The generic points provide a set of topics as a starting point for policy and intervention planning activities, while the 15 associations support the identification of place-specific leverage points for strengthening adaptive capacity.

An adaptation planning approach

Here we discuss four benefits of using leverage points for adaptive capacity in climate change adaptation planning that enable transformational solutions.

Guidance on where to intervene

Adaptation measures need to be tailored to the place and context in order to be meaningful and effective. A benefit of the leverage points for adaptive capacity is the potential to identify places to intervene with the prospect to create change by addressing the associations emerging from the 15 associations and the four generic leverage points. Knowing where to intervene creates efficiency in the planning process.

Ability to deal with complexity

The agricultural sector, highly susceptible to climate change, is influenced by a number of system dynamics such as natural disasters, population growth, changing consumption habits, poverty, trade agreements, access to water and armed conflicts to name a few (Müller 2013; Misra 2014; Salehyan and Hendrix 2014). This complexity creates uncertainty, which makes it hard to develop reliable future scenarios of climate change impacts often used as a basis for decision-making (Müller 2013). An alternative to this so-called risk- or hazard-based approach using scenarios of future climate impacts is the so-called vulnerability approach, which focuses on making decisions based on present needs of people (Füssel 2007a). The benefit of the vulnerability approach is that it is in a better place to embrace complexity compared with the risk-based approach. Also community-based adaptation focusing on participatory processes, capacity building and building on local cultural norms has gained much ground (Dodman and Mitlin 2013; Kirkby et al. 2018). We contend that leaning on leverage points for strengthening adaptive capacity offers an alternative option to the existing adaptation planning approaches. The ability of the leverage point framework to embody complex settings is thanks to its systems approach offering entry points and framing of thinking around a range of system levels.

Embracing both causal and teleological decision-making

The systemic leverage points guide critical reflection both around the present and future needs and wishes of farmers, and combines both causal and teleological means to bring change (Fischer and Riechers 2019). This provides a novel approach to the number of decision-making approaches leaning on mainly causal decision-making such as the Dynamic Adaptive Policy Pathways (Haasnoot et al. 2013), Robust Decision-Making (Lempert et al. 2010) and Info-Gap Decision Theory (Korteling et al. 2013), which have been developed during the past decade to deal with the deep uncertainty that adaptation planning is faced with.

Ability to target deep, normative systemic structures

Another benefit of using leverage points for strengthening adaptive capacity is the potential to target deep, transformative change. This responds to the findings of Nightingale et al. (2020) that call for going beyond simple technical fixes when addressing climate solutions by turning to values and experimental and plural ways of knowing, in other words elements forming part of the normative structures of society. Sustainability and development are not just technical issues but depend deeply on political values and choices (Scoones and Stirling 2020) in this case linked to traditional rules concerning, for example, land tenure, practices of agricultural extension agents and values linked to possibilities to participate in social platforms. Policy interventions tend to target weak leverage points that do not have the potential to create far-reaching change (Fischer and Riechers 2019). This tendency is exacerbated due to increasingly stringent donors reporting requirements encouraging a stronger focus on activities that are easy to monitor, such as activities that are possible to track through numerical indicators. Transformative change for example in social norms is, however, harder to track through indicators, which creates a perverse incentive to move away from targeting phenomena with the potential for more substantive or deeper change (Cornwall and Rivas 2015). Leverage points will of course not directly be able to change this trend but offer a way to, in a comprehensive and intuitive way, target deep entry points to change.

Four interlinked, generic leverage points for adaptive capacity

Our findings clearly demonstrate that it is possible to identify new place-specific leverage points. Based on

the 15 place-specific leverage points the study identified four generic leverage points: gender equality, social learning, information and knowledge, and access to finance. We advance the scientific discussion related to adaptive capacity by pinpointing the fundamental importance of these four topics as highly important vehicles for strengthening adaptive capacity. However, we argue that in order to maximize positive change these four topics should not be targeted in isolation from each other but rather as an ensemble. This builds on the working theory presented by Fischer and Riechers (2019) on the importance of interaction between leverage point realms and how more shallow leverage points make momentum also for deeper change. Manlosa et al. (2019) call these more shallow-level shifts 'sparks'. Further studies on this are needed. Noteworthy is that gender aspects as well as the role of social networks and institutional collaboration including knowledge exchange were identified as areas needing further research in a study investigating research gaps in agricultural climate change adaptation science (Davidson 2016).

Gender equality

We identified a gender disparity that disadvantaged women in relation to most of the topics that emerged in the interviews. This reflects the specific challenges and gaps in access to a number of key resources that small-scale women farmers are faced with (Doss et al. 2014; Quisumbing et al. 2015; Eastin 2018). The importance of the gender aspect in climate change adaptation policy and intervention is recognized in the existing literature (Caretta and Börjeson 2015; Cramer et al. 2016; Bryan et al. 2018). At the same time gender, especially as part of the development agenda, is criticized as having limited impact and that the gender agenda has been watered down despite it being generally acknowledged as an important topic for sustainable development (Parpart 2014). Gender equality related policy planning and implementation is facing a number of barriers, such as a lack of capacity of the persons implementing the interventions (Bryan et al. 2018), insufficient funding, and a lack of commitment to gender matter. The latter translates into poor advancement of gender equality and gender empowerment in policy implementation among international development agencies (Parpart 2014). These are worrying findings considering our study's result of the importance of gender equality to promote adaptive capacity but they can also be seen as opportunities to create positive change. Of the four identified generic leverage points gender equality is the one addressing social norms that, while challenging to address, also holds great potential to create systemic change. Addressing the three other generic leverage points will support an enabling environment that will facilitate advances in gender equality.

Information and knowledge

In the study, the data showed that accessing useful and understandable information was a challenge for many of the informants. Many felt that they did not have the necessary information to make informed decisions on farming practices and diversification of livelihoods especially in the light of the challenges climate change poses in the study area. 'Lack of knowledge' has broadly been discussed in the literature to be an impediment to climate change adaptation and to adaptive capacity (Parry et al. 2007; Williams et al. 2015).

Social learning

The previous leverage point goes hand in hand with social learning. A person has to be able to process and interpret information before information can turn into knowledge (Williams et al. 2015). Even then there is no guarantee that it will lead to improved climate change adaptation due to, for example, cognitive barriers (Grothmann and Patt 2005). Social learning has been studied in the past in the context of natural resource management and collective and wicked problems in sustainability (Wals and Rodela 2014). A broad definition by Ensor and Harvey (2015) defines social learning to facilitate knowledge sharing, joint learning, and co-creation of experiences between stakeholders around a shared purpose in ways that: 1) take learning and change beyond the individual to communities, networks or systems, and 2) enable new, shared ways of knowing that lead to changes in practice. The leverage points identified for the study area address social capital through the creation of self-organized social platforms that build trust and social cohesion. Social learning not only addresses gaps in knowledge but also builds social capital including trust, enhancing reciprocity and exchanges (bonding capital), and improving connectedness to networks and groups (Pretty and Buck 2002). Strong social capital is important in times of hardship, for example after a storm or flooding, and can determine whether people help each other or not (Adger 2003).

As climate change interventions often come with a high price tag and resources are scarce, further strengthening and cross-pollinating local adaptation practices are valuable (Nyong et al. 2007). In the study, a number of already existing adaptation measures were reported as people through generations have found ways to cope with climate variability such as droughts and floods. It was not clear based on the data collected which of the existing measures could be classified as local knowledge and which of the adaptation practices stemmed from the

agricultural extension officers. It was probably a mixture of both. Integrating local knowledge in adaptation planning has the potential to improve the often low uptake of new technologies and the low success rate in past adaptation endeavours (Nyong et al. 2007). There are, however, also critical voices towards the *integration* of local knowledge into adaptation processes in the Global South. It is seen that the adaptation planning process including the integration of local knowledge might still be led by external parties imposing a Western world view (Diver 2017). In response to this criticism there is a call to move from 'integrating' local knowledge to co-producing knowledge (Nalau et al. 2018). In the case of our study area, local culture and tradition would most likely not include women as equal parties in a knowledge co-production exercise. This highlights the importance of being mindful of and addressing gender inequalities in adaptation planning and underlines our earlier claim that the four generic leverage points should not be regarded in isolation but rather as an ensemble of topics, together having the potential to create positive change.

Access to finance

The importance of access to finance for adaptive capacity has been proved (Caretta 2014; Simotwo et al. 2018). Despite the fact that nearly half (41%) of the women interviewed in this study had access to credit, it was clear that their level of adaptive capacity was very weak. Several challenges were listed related to the existing microcredit schemes, which made it a viable option for only a few. To better understand the barriers of the current microcredit system and how to overcome these merits further study. We consider that 'access to finance' alone will not have the power to substantially improve adaptive capacity. Together with the other three generic leverage points, access to finance has the potential to substantially improve adaptive capacity and create positive change.

Limitations and future directions

We contend that combining the two established concepts to form 15 associations has proved fruitful but further testing in other contexts and geographical locations is needed. To facilitate further testing and to apply the constellation more broadly, further development would be beneficial. In this study we have focused only on the design realm including three, deep leverage points, which provided a rich set of data. Further studies including the other three realms parameters, feedbacks and intent (see Table 1) are needed to deepen the understanding of how leverage points could serve adaptation planning.

Using leverage points to strengthen adaptive capacity cannot be seen as a pure quick fix for identifying suitable entry points for climate change adaptation planning as the analysis requires an in-depth understanding of the local context including cultural norms, beliefs and values, i.e. topics often challenging to collect data on and topics that also can be difficult to act on. Resistance related to gender equality work has for example been documented (Colpitts 2019; Ratele 2015).

There is a limited amount of peer reviewed articles on evaluations of operationalized efforts to strengthen adaptive capacity (Whitney et al. 2017). Likewise, literature on evaluated initiatives where identified systemic leverage points have been operationalized is also scarce. This makes it questionable to make strong claims about the potential usefulness of leverage points, which is broadly stated in the existing leverage point literature. We recommend further research on evaluations on existing operationalized leverage point initiatives.

Finally, we also call for further academic discussion on the methodological approach for the identification of leverage points for adaptive capacity. The authors invite the scientific community to further discuss and test the three criteria used by the authors. The existing scientific literature on frameworks and methods is scarce.

Acknowledgements

We thank the Ghanaian team Ms. Rahajatu Buwah, Mr. Abdul-Razak Mohammed, Mr. Siisu Abubakari Baba, Ms. Hamdia Dangimah Tahiru and Ms. Salimata Yakubu for their contribution in the data collection and focus group facilitation. We also thank the persons who participated in this research and the three anonymous reviewers whose comments greatly improved the manuscript. We finally thank Hanna Huitu, Natural Resources Institute Finland, for the map visualization.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by the European Union LEAP-Agri ERA-Net and the Academy of Finland through the project Participatory Pathways to Sustainable Intensification. Innovation platforms to integrate leguminous crops and inoculants into small-scale agriculture and local value chains.

Discloser statement

There is no financial interest or benefit arising from this research.

ORCID

Linda M. Rosengren http://orcid.org/0000-0002-8365-8726
Christopher M. Raymond http://orcid.org/0000-0002-7165-885X
Mila Sell http://orcid.org/0000-0003-0209-5851
Hilkka Vihinen http://orcid.org/0000-0002-8300-0721

References

Abbam T, Johnson FA, Dash J, Padmadas SS. 2018. Spatiotemporal variations in rainfall and temperature in Ghana over the twentieth century, 1900–2014. Earth Space Sci. 5(4):120–132.
Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, Jager NW. 2017. Leverage points for sustainability transformation. Ambio. 46(1):30–39.
Adger WN. 2003. Social capital, collective action, and adaptation to climate change. Econ Geogr. 79 (4):387–404.
Agadjanian V, Ezeh AC. 2000. Polygyny, gender relations, and reproduction in Ghana. J Comp Fam Stud. 31(4):427–441.
Angeler DG, Fried-Petersen HB, Allen CR, Garmestani A, Twidwell D, Chuang W-C, Sundstrom SM. 2019. Adaptive capacity in ecosystems *advances in ecological research*. Vol. 60, London: Elsevier. p. 1–24.
Aniah P, Kaunza-Nu-Dem MK, Ayembilla JA. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. Heliyon. 5(4):e01492.
Apusigah AA. 2009. The gendered politics of farm household production and the shaping of women's livelihoods in Northern Ghana. Feminist Afr. 12(12):51–67.
Armah FA, Luginaah I, Hambati H, Chuenpagdee R, Campbell G. 2015. Assessing barriers to adaptation to climate change in coastal Tanzania: does where you live matter? Popul Environ. 37(2):231–263.
Atta GP. 2015. Education inequality: how patriarchy and policy collide in Ghana. Int J Humanities Soc Sci. 57 (1):11–19.
Bernier Q, Meinzen-Dick RS, Kristjanson PM, Haglund E, Kovarik C, Bryan E, Silvestri S 2015. Gender and institutional aspects of climate-smart agricultural practices: evidence from Kenya. *CCAFS Working Paper No. 79*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)
Boafo YA, Saito O, Jasaw GS, Otsuki K, Takeuchi K. 2016. Provisioning ecosystem services-sharing as a coping and adaptation strategy among rural communities in Ghana's semi-arid ecosystem. Ecosyst. Serv. 19:92–102.
Braun V, Clarke V, Hayfield N, Terry G. 2019. Thematic analysis. In: Liamputtong P, editor. Handbook of research methods in health social sciences. Singapore: Springer; p. 843–860.
Brown K, Westaway E. 2011. Agency, capacity, and resilience to environmental change: lessons from human development, well-being, and disasters. Annu Rev Environ Resour. 36:321–342.
Bryan E, Bernier Q, Espinal M, Ringler C. 2018. Making climate change adaptation programmes in sub-Saharan Africa more gender responsive: insights from implementing organizations on the barriers and opportunities. Clim Dev. 10(5):417–431.
Caminade C, Kovats S, Rocklov J, Tompkins AM, Morse AP, Colón-González FJ, Lloyd SJ. 2014. Impact of climate change on global malaria distribution. Proc Natl Acad Sci. 111(9):3286–3291.
Caretta MA. 2014. "Credit plus" microcredit schemes: a key to women's adaptive capacity. Clim Dev. 6(2):179–184.
Caretta MA, Börjeson L. 2015. Local gender contract and adaptive capacity in smallholder irrigation farming: a case study from the Kenyan drylands. Gend Place Culture. 22(5):644–661.
Chan KM, Boyd DR, Gould RK, Jetzkowitz J, Liu J, Muraca B, Selomane O. 2020. Levers and leverage points for pathways to sustainability. People Nat. 2(3):693–717.
Cinner JE, Adger WN, Allison EH, Barnes ML, Brown K, Cohen PJ, Lau J. 2018. Building adaptive capacity to climate change in tropical coastal communities. Nat Clim Chang. 8:117–123.
Cohen PJ, Lawless S, Dyer M, Morgan M, Saeni E, Teioli H, Kantor P. 2016. Understanding adaptive capacity and capacity to innovate in social–ecological systems: applying a gender lens. Ambio. 45(3):309–321.
Colpitts E. 2019. Engaging men and boys to prevent gender-based violence in South Africa: possibilities, tensions and debates. Can J Dev Stud. 40(3):423–439.
Cornwall A, Rivas A-M. 2015. From 'gender equality and 'women's empowerment' to global justice: reclaiming a transformative agenda for gender and development. Third World Q. 36(2):396–415.
Cramer L, Förch W, Mutie I, Thornton PK. 2016. Connecting women, connecting men: how communities and organizations interact to strengthen adaptive capacity and food security in the face of climate change. Gend Technol Dev. 20(2):169–199.
Davidson D. 2016. Gaps in agricultural climate adaptation research. Nat Clim Chang. 6:433–435.
Descheemaeker K, Oosting SJ, Tui SH-K, Masikati P, Falconnier GN, Giller KE. 2016. Climate change adaptation and mitigation in smallholder crop–livestock systems in sub-Saharan Africa: a call for integrated impact assessments. Reg Environ Change. 16(8):2331–2343.
Diver S. 2017. Negotiating Indigenous knowledge at the science-policy interface: insights from the Xáxli'p community forest. Environ Sci Policy. 73:1–11.
Dodman D, Mitlin D. 2013. Challenges for community-based adaptation: discovering the potential for transformation. J Int Dev. 25(5):640–659.
Doss C, Meinzen-Dick R, Bomuhangi A. 2014. Who owns the land? Perspectives from rural ugandans and implications for large-scale land acquisitions. Fem Econ. 20 (1):76–100.
Dreborg KH. 1996. Essence of backcasting. Futures. 28 (9):813–828.
Dumenu WK, Obeng EA. 2016. Climate change and rural communities in Ghana: social vulnerability, impacts, adaptations and policy implications. Environ Sci Policy. 55:208–217.
Eastin J. 2018. Climate change and gender equality in developing states. World Dev. 107:289–305.
Engle NL. 2011. Adaptive capacity and its assessment. Global Environmental Change. 21(2):647–656.
Ensor J, Harvey B. 2015. Social learning and climate change adaptation: evidence for international development practice. Wiley Interdiscip Rev Clim Change. 6:509–522.
Fischer J, Riechers M. 2019. A leverage points perspective on sustainability. People Nat. 1(1):115–120.
Fuchs S, Thaler T. 2017. Tipping points in natural hazard risk management: how societal transformation can provoke

policy strategies in mitigation. J Extreme Events. 4(1), 1750006.
Füssel H-M. 2007a. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustainability Sci. 2(2):265–275.
Füssel H-M. 2007b. Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change. 17(2):155–167.
Garschagen M, Soletzki W. 2017. Tipping points in adaptive capacity and adaptation processes. J Extreme Events. 4:1.
Gbegbelegbe S, Serem J, Stirling C, Kyazze F, Radeny M, Misiko M, Sonder K. 2018. Smallholder farmers in eastern Africa and climate change: a review of risks and adaptation options with implications for future adaptation programmes. Clim Dev. 10(4):289–306.
Ghana Statistical Service, 2019, Ghana Living Standars Survey 7 (GLSS 7)
Grothmann T, Patt A. 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environmental Change. 15(3):199–213.
Haasnoot M, Kwakkel JH, Walker WE, Ter Maat J. 2013. Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change. 23:485–498.
Hallegatte S. 2009. Strategies to adapt to an uncertain climate change. Global Environmental Change. 19: 240–247.
Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kanae S. 2013. Global flood risk under climate change. Nat Clim Chang. 3(9):816–821.
IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A. N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]*. Cambridge (United Kingdom and New York, NY, USA): Cambridge University Press.
Kirkby P, Williams C, Huq S. 2018. Community-based adaptation (CBA): adding conceptual clarity to the approach, and establishing its principles and challenges. Clim Dev. 10(7):577–589.
Korteling B, Dessai S, Kapelan Z. 2013. Using information-gap decision theory for water resources planning under severe uncertainty. Water Resour Manage. 27(4):1149–1172.
Lempert RJ, Popper SW, Bankes SC. 2010. Robust decision making: coping with uncertainty. Futurist. 44(1):47.
Manlosa AO, Schultner J, Dorresteijn I, Fischer J. 2019. Leverage points for improving gender equality and human well-being in a smallholder farming context. Sustainability Sci. 14(2):529–541.
Meadows DH. 1999. Leverage points: places to intervene in a system. Hartland (WI): The Sustainability Institute.
Menghistu HT, Abraha AZ, Tesfay G, Mawcha GT. 2020. Determinant factors of climate change adaptation by pastoral/agro-pastoral communities and smallholder farmers in sub-Saharan Africa. Int J Clim Change Strategies Manage. 12(3):305–321.
Misra AK. 2014. Climate change and challenges of water and food security. Int J Sustainable Built Environ. 3 (1):153–165.
Muchuru S, Nhamo G. 2019. A review of climate change adaptation measures in the African crop sector. Clim Dev. 11(10):873–885.
Müller C. 2013. African lessons on climate change risks for agriculture. Annu Rev Nutr. 33:395–411.
Nalau J, Becken S, Schliephack J, Parsons M, Brown C, Mackey B. 2018. The role of indigenous and traditional knowledge in ecosystem-based adaptation: A review of the literature and case studies from the Pacific Islands. Weather Clim Soc. 10(4):851–865.
Nightingale AJ, Eriksen S, Taylor M, Forsyth T, Pelling M, Newsham A, Jones L. 2020. Beyond Technical Fixes: climate solutions and the great derangement. Clim Dev. 12(4):343–352.
Nyong A, Adesina F, Elasha BO. 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation Adapt Strategies Global Change. 12(5):787–797.
Oloukoi G, Fasona M, Olorunfemi F, Adedayo V, Elias P. 2014. A gender analysis of perceived climate change trends and ecosystems-based adaptation in the Nigerian wooded savannah. Agenda. 28(3):16–33.
Osei F, Stein A. 2017. Spatio-temporal analysis of small-area intestinal parasites infections in Ghana. Sci Rep. 7(1):1–11.
Owusu-Mensah I. 2014. Politics, chieftaincy and customary law in Ghana's fourth republic. J Pan Afr Stud. 6 (7):261–278.
Parpart JL. 2014. Exploring the transformative potential of gender mainstreaming in international development institutions. J Int Dev. 26(3):382–395.
Parry M, Parry ML, Canziani O, Palutikof J, Van der Linden P, Hanson C (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.
Pretty J, Buck L. 2002. Social capital and social learning in the process of natural resource management. In: Barrett C, Place F, & Aboud A, editor. Natural resources management in African agriculture: understanding and improving current practices. Wallingford (UK): CAB International; p. 23–34.
Pretty JN (2003). Social capital and connectedness: issues and implications for agriculture, rural development and natural resource management in ACP countries. CTA Working Document;8032. CTA, Wageningen (The Netherlands)
Proust K, Newell B, Brown H, Capon A, Browne C, Burton A, Zarafu M. 2012. Human health and climate change: leverage points for adaptation in urban environments. Int J Environ Res Public Health. 9(6):2134–2158.
Quist, J. & Vergragt, P. (2006). Past and future of backcasting; The shift to stakeholder participation and a proposal for a methodological framework. *Futures*, *38* (9), 1027–1045.
Quisumbing AR, Rubin D, Manfre C, Waithanji E, Van den Bold M, Olney D, Meinzen-Dick R. 2015. Gender, assets, and market-oriented agriculture: learning from high-value crop and livestock projects in Africa and Asia. Agric Human Values. 32(4):705–725.
Ratele K. 2015. Working through resistance in engaging boys and men towards gender equality and progressive masculinities. Cult Health Sex. 17(sup2):144–158.
Rhoades RD, McCuistion KC, Mathis CP. 2014. A systems thinking approach to ranching: finding leverage to mitigate drought. Rangelands. 36(6):2–6.
Ripple WJ, Wolf C, Newsome TM, Barnard P, Moomaw WR. 2019. World scientists' warning of a climate emergency. BioScience. 70(1):8–12.

Roy SS. 2018. Climate change in the global south: trends and spatial patterns. In: Roy SS, editor. Linking gender to climate change impacts in the global south. Cham: Springer; p. 1–25.
Salehyan I, Hendrix CS. 2014. Climate shocks and political violence. Global Environmental Change. 28:239–250.
Saunders B, Sim J, Kingstone T, Baker S, Waterfield J, Bartlam B, Jinks C. 2018. Saturation in qualitative research: exploring its conceptualization and operationalization. Qual Quant. 52(4):1893–1907.
Scoones I, Stirling A. 2020. Uncertainty and the politics of transformation. In: Scoones I, Stirling A, editors. The politics of uncertainty. Oxon: Routledge; p. 1–30.
Serdeczny O, Adams S, Baarsch F, Coumou D, Robinson A, Hare W, Reinhardt J. 2017. Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. Reg Environ Change. 17 (6):1585–1600.
Shackleton S, Ziervogel G, Sallu S, Gill T, Tschakert P. 2015. Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. Wiley Interdiscip Rev Clim Change. 6(3):321–344.
Siders A. 2019. Adaptive capacity to climate change: A synthesis of concepts, methods, and findings in a fragmented field. Wiley Interdiscip Rev Clim Change. 10(3):e573.
Simotwo HK, Mikalitsa SM, Wambua BN. 2018. Climate change adaptive capacity and smallholder farming in trans-mara East sub-County, Kenya. Geoenviron Disasters. 5(1):1–14.
Sonwa DJ, Dieye A, El Mzouri E-H, Majule A, Mugabe FT, Omolo N, Brooks N. 2017. Drivers of climate risk in African agriculture. Clim Dev. 9(5):383–398.
Sultan B, Gaetani M. 2016. Agriculture in West Africa in the twenty-first century: climate change and impacts scenarios, and potential for adaptation. Front Plant Sci. 7:1262.
Sylla MB, Nikiema PM, Gibba P, Kebe I, Klutse NAB. 2016. Climate change over West Africa: recent trends and future projections. In: Yaro J, Hesselberg J, editors. Adaptation to climate change and variability in rural West Africa. Cham: Springer; p. 25–40.
Tenkorang EY, Owusu AY, Yeboah EH, Bannerman R. 2013. Factors influencing domestic and marital violence against women in Ghana. J Fam Violence. 28 (8):771–781.
Tongco MDC. 2007. Purposive sampling as a tool for informant selection. Ethnobotany Res App. 5:147–158.
Twyman J, Green M, Bernier Q, Kristjanson PM, Russo S, Tall A, McKune S (2014). Adaptation actions in Africa: evidence that gender matters. Working Paper No. 83. CCAFS, CGIAR.
Wals AE, Rodela R. 2014. Social learning towards sustainability: problematic, perspectives and promise. NJAS-Wageningen J Life Sci. 69:1–3.
Wheeler T, Von Braun J. 2013. Climate change impacts on global food security. Science. 341(6145):508–513.
Whitney CK, Bennett NJ, Ban NC, Allison EH, Armitage D, Blythe JL, Kaplan-Hallam M. 2017. Adaptive capacity: from assessment to action in coastal social-ecological systems. Ecol Soc. 22(2):22.
Williams C, Fenton A, Huq S. 2015. Knowledge and adaptive capacity. Nat Clim Chang. 5(2):82–83.
Wossen T, Berger T. 2015. Climate variability, food security and poverty: agent-based assessment of policy options for farm households in Northern Ghana. Environ Sci Policy. 47:95–107.
Yengoh GT, Armah FA, Onumah EE, Odoi JO. 2010. Trends in agriculturally-relevant rainfall characteristics for small-scale agriculture in Northern Ghana. J Agr Sci. 2(3):.3(14).

Appendix 1. Interview guidelines for farmer sample

Introduction

Interviewer says: Before we start I would like to explain a bit about the project that we work with (do the GDPR and ethics protocol).
Now we are ready to start the interview: (Put the recorder on!)
Interviewer states: (this needs to be recorded!)

(1) The date
(2) The place
(3) Name of interviewee
(4) Name of interviewer

Interviewer says: Many thanks for taking the time to discuss. I will ask you questions and please note that there are no right or wrong answers. I am only interested to hear what you think. Please don't hesitate to ask for clarification if needed.

Interview questions

First I would like to discuss a bit about your farm and your farming practices

(1) How many separate plots of land do you have, what size are they and what do you grow? Do you grow any legumes – cowpea, soybean, groundnut, common bean and/or bambara groundnut?
(2) Do you have any livestock? (Yes/No) If yes, what type and how many?
(3) What kind of equipment do you own or have access to if you don't own it yourself; for example, tools, motorcycle or a tractor? (anything else)
(4) What kind of equipment would you need to improve your farming?
(5) Do you own the land that you farm?
(6) What would it require for you to get more land to farm? Are there any customs or cultural traditions or any systems, formal and traditional, that enable or constrain you from accessing more land?

Now I would like to discuss a bit about the technology that you have

(7) Do you have a mobile phone? (Yes/No)
(8) Do you always/usually have airtime?
(9) Are you able to connect to the internet?
(10) From where do you get information about new technology for example for farming practices?
(11) Have you heard about rhizobium inoculants? (Yes/No). Biofertilizers used together with legumes instead of nitrogen fertilizer. What have you heard about rhizobium inoculants?

Now I would like to discuss a bit about your livelihood

(12) What are your income sources?
(13) Are there any other income-generating activities that you could think of doing?

(14) What would you need (investment, support, knowledge? – probe) to be able to engage in these alternative income sources?
(15) Do you have access to credit? (Yes/No)
(16) From where do you get information about how to get credit?
(17) Are there any traditions or customs or any formal systems or rules that affect your access to credit?
(18) Do you have access to healthcare?

Now I would like to discuss the weather and climate

(19) Is your experience that the weather has changed compared with when you were a child? (Yes/No) If so, how?
(20) (If yes) How has this affected your everyday life?
(21) (If yes) If you have changed your practices to cope so far then how have you done it?
(22) How have others in your community responded to changing weather?
(23) Do people help each other when faced with hardship/crises? (Yes/No) If so, how? If not, why not?
(24) From where do you get information about the weather to know when to sow or harvest or when there is a drought or flooding coming?
(25) Do you think you have enough information about the weather? (Yes/No) If no, what additional information or support would you need in order to better cope with changing weather?
(26) Do you feel that you have enough support from institutions, formal or traditional, to cope with the climate? (Yes/No) If no, what more support would you need?

Now I am interested to discuss the support networks that you have

(27) Which organizations, groups or networks are you a member of and what do they do?
(28) From where do you get information about existing networks, associations, NGOs and other organizations that you could join that could support you? Please describe.
(29) Do you feel that you are free to participate in any organization that you want to? If not, why not?
(30) Do you feel that your opinions and thoughts are heard by a larger group such as decision makers (through any of these groups or organizations that you are active in)? If so, how? If not, why not?
(31) Do you feel you can decide yourself about most aspects of your life? (Where you live, what you do, how many children you have.) If so, how? If not, why not?

Finally, I would like to discuss education

(32) What is your level of education and what is the highest level of education within your household? Years of schooling.
(33) Where and when do you normally learn new things?
(34) Do you feel you have enough opportunities to learn new things?
(35) Have you attended any sessions with the extension workers? (Yes/No)
(36) If yes, what are your thoughts on these, are they useful and what have you learned? (Social learning.) If so, how? If not, why not?

Appendix 2. Interview guidelines for key informant sample

The questions were tailored to fit the expertise of the informant. All of the following questions were therefore not asked to every key informant.

Food system, role of the different actors within the system and potential for change

The food system is the whole network of actors involved in the food chain, from producers to sellers and processors, to consumers, but also to the political and cultural actors making decisions about economic and environmental issues in the region.

Questions:

(1) First, what does the food in the local food system mainly consist of? Which crops are grown and which basic products produced? What food do people in general consume?
(2) To get a good overview of how you see the dominant local food system, could we draw a map of the most important actors and their relation to each other? We can differentiate three levels: agricultural production system, value chain, and support structures (such as policy and extension).
(3) Are there many alternative paths from producer to consumers within this system? What are they?
(4) Now, looking at this map, who would you say are the most important actors in terms of making decisions about what to grow?
(5) Who would you say are the most important actors in terms of making decisions about what is processed from these crops – who decides?
(6) Is decision-making or participation somehow restricted based on issues such as gender or ethnicity?
(7) Do you believe people are generally happy with the current food system? If not, what are the aspects they are not happy with?
(8) Do you feel people generally consume healthy foods? Are there big differences in consumption patterns of different groups within the system?
(9) Who are the actors with power to influence change in the food system?
(10) Do you see any examples of niche/marginal food system approaches developing in the community? What type of activity or processes are these? Who/what are the drivers of these processes? How do they fit into the overall dominant food system? Are there conflicts between niche actors and others within the dominant food system?
(11) Do you feel that consumers have power to influence the food system through their choices? Are there any types of consumer organizations pushing for change? For example, better access to nutrition/information/something else?
(12) And what about farmers associations? Are they able to influence the food system/changes in the food system? What type of issues are they most concerned with?
(13) Do people in general – or any specific stakeholder group within the food system – discuss environmental aspects of the current production systems?
(14) Do you believe there are environmental pressures that will eventually force changes within the current food system? What are these pressures? What kind of changes do you envision? Can any of the niche approaches mentioned before play a part in this change?

(15) How much does local policy influence the food system or possible changes within the system? What are the most important support structures for local producers (crops and products), for example, subsidies, schemes, extension?
(16) How much do you feel that global markets and international corporations influence the local food system?
(17) What about local business development and innovation? Is there local capacity to engage in such activities? Who are the main actors? Are farmers involved in innovation activity?
(18) Do you feel that local businesses stand a chance in relation to international corporations? Could local consumers play a role in driving demand for local products?
(19) If you think about the best solutions/pathways towards a food system that benefits all the actors of the food chain, what do you think are the most important elements?
(20) What are the main constraints or barriers to achieving such a change?
(21) What is the role of technology in developing the food system in new directions?

Appendix 3. Backcasting exercise with the focus groups

This is the guidance for the facilitators who facilitated the backcasting exercises during the two focus group discussions.
Facilitator says: The participants will form two groups after the introduction to the exercise.

Creating the vision of the desired future

Facilitator says: We are now going to visualize the future of your children or grandchildren in 20 years' time. The person is strong and resourceful having all the conditions to live a good life. The person is still living in your home village and wants to continue doing that, working with farming and possibly also with something else. The climate is still being difficult with dry spells and erratic rain patterns. But your child has found ways to cope and is living a good life.
Discussions will start among the two groups facilitated by the two group facilitators.

Question 1

Please describe what your children are occupied with. Do they only farm and in that case what do they farm? Or do they also have other income-generating activities?

Question 2

What type of resources do your children have in order to be successful? Probe: owned and rented resources, access to credit, education and healthcare.

Question 3

What type of organization, network or association are your children active in? Can you think of any new type of organization that would be beneficial?

Question 4

From where will your children gain new knowledge? Probe: radio, school, extension service or other sources?

Question 5

In what role or capacity do you see this person, your child or grandchild, in relation to others in the community?

Steps for how to get to the vision

Now when we know what we would like the future of our children or grandchildren to look like then let's think what is preventing us from making this a reality.

Question 1

What is needed to make this happen?

Question 2

What type of knowledge and information would your child or grandchild need?

Question 3

Who should be responsible to make this happen? Which institutions, stakeholders or groups should be involved? Can this happen within the existing groups or do we need to create new collaborations among interest groups or within a community or stakeholder group?

Question 4

What will make this person be respected and his or her opinion be heard?

Question 5

What can YOU do for this to happen? What is needed for an individual/organization to make it happen?